VLSI IMPLEMENTATION FOR BIOLOGICAL SENSING APPLICATION

SHORT SYNOPSIS

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Certificate

I hereby declare that the short synopsis "VLSI Implementation for Biological Sensing Application" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Electronics and Communication Engineering under faculty of Engineering and Technology of Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2013.

It is a bona fide record of original work carried out under the supervision of Dr. Naresh Grover and has not been submitted in full or part to any other university or institute for degree or diploma. Further, it is certified that short synopsis is plagiarism free and proof has been submitted.

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ABSTRACT

Cardiovascular disease is a type of disease which increases the death rate and probably creates the fatal risk hence a regular heart check-up is essential. Many techniques and methods have been fitted with still-growing adaptations and researches to examine and evaluate the ECG signals on a beat-to-beat basis. Maximum research rotates all over the arrhythmia classification, heart rate observation and blood pressure determination, which need proper judgment of rhythm irregularity. Regular heart disease diagnosis is very cumbersome and time consuming process and to reduce such complexity there is a requirement to develop a single system device for heart disease diagnosis which is based on the morphological characteristics of ECG and blood pressure measurement. The proposed method will be able to diagnose the heart disease in two stages, first stage includes processing and calculation of ECG parameter and then will classify the arrhythmia type (irregular heartbeat) using proposed algorithm and the disease will be found in the later stage using the type of arrhythmia and some other symptoms of disease. The algorithm will be tested over MIT-BIH Arrhythmia database. The computational complexity will be reduced using only low frequency sub-bands for feature extraction. There is no system in the existing state of art which uses ECG with other body parameters for efficient diagnosis of heart diseases. It is proposed to design a system using MATLAB followed by HDL (Verilog) and implement on FPGA and its performance shall be tested and verified. The proposed system will be fast enough to generate alarm in time so that proper assistance can be made to patient. The Cardiovascular disease commonly found in humans can be precisely detected using this proposed method. For tele-monitoring the patient this system can be very useful. Using the proposed method various arrhythmias can be detected from recorded and real time data.

Key words: ECG, QRS complex, R peak, LBBB and RBBB, MATLAB, MIT-BIH, HDL.

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1. INTRODUCTION

Cardiovascular disease is a major health problem in every part of world, causing increase in death rate. The noninvasive efficient diagnosis of heart is possible through study of electrocardiogram (ECG) of the patient under observation. An electrocardiogram (ECG or EKG) also known as heart waves which measures the heart's electrical activity over the time with respect to different reference planes. ECG is widely used to find out the cardiac problems, since it measures the contractile electrical activity of the heart generated over the cardiac cycle through different electrodes placed at different places on the body surface, (Abdelliche and Charef 2009). The work pressure of ECG diagnosis and analysis has been raised at an epidemic rate due to increased number of cases of heart disorder in human being. Hence it became unavoidable to automate the ECG diagnosis up to its extremes. The heartbeat produces a series of waves with a time-variant morphology called the heart rhythm in terms of bits per minute which may be simply calculated by counting the easily detectable waves, (Trivedi and Ayub 2014; Elgendi, Jonkman and De 2009). Based on the difference in position, chest configuration, anatomy of the heart, age, size, relatively body weight and various other factors, ECG of every person is different. An ECG signal is composed of number of ECG cycles and each ECG cycle is consists of different peaks and intervals i.e. P, Q, R, S and T peaks and PR and ST interval, (Chen and Duan 2005; Zhang and Lian 2009). These pattern vectors are used to separate the ECG into two categories one is normal and another one is abnormal class for the purpose of disease detection, (Yeha and Wanga 2008). The different stages to process the ECG are data acquisition, feature extraction, measurement of parameter and classification of disease. In data acquisition stage the ECG signals are obtained from MIT/BIH arrhythmia database and then digitized. In the next stage (i.e. first stage of filtering), to remove baseline wander and high frequency noise which smoothen the unfiltered data, the ECG signal is passed through baseline wandering removal function where most of the noise is eliminated. Then all peaks and intervals exist in the ECG signal i.e. P, Q, R, S and T peaks and PR and ST intervals and QRS complex are obtained in the feature extraction stage in the presence of noisy peaks. Thereafter in the second filtering stage, the extra peaks from the ECG signal other than the actual P, Q, R, S and T peaks are removed and the information of amplitude, duration, etc. from the actual peaks is obtained. In the last block, these ECG parameters and indicative rules are used to divide the ECG into normal and

abnormal class and once it is observed as abnormal then it is further classified to find the type of disease to which it belongs. Once the features present in an ECG signal get determined then various arrhythmias can be detected like Bradycardia, Tachycardia, Supraventricular Tachycardia, Ventricular Tachycardia, Bundle Branch Block and Incomplete Bundle Branch Block. Other body parameters like BP, sugar etc. shall be used along with ECG classification to specify the particular type of disease.

2. LITERATURE SURVEY

To detect the arrhythmia in long-duration ECGs, soft computing techniques are widely used and they are normally distributed into three stages. The first one is preprocessing stage where removal of noise from ECG signal is being done. Second stage measures and extracts all the important ECG features from ECG. In the third stage any abnormality of cardiac beat is classified using the above features. For arrhythmia detection the literature proposed different types of systems. In all these systems variation lies mainly in the last two stages the technique utilize. Depending on the different techniques utilized these systems can be categorized into one of the following:

1) Digital Signal Analysis
2) Rule-Based
3) Fuzzy Logic
4) Artificial Neural Network (ANN) and
5) Genetic Algorithm (GA)

Each system exhibits its own particular characteristics. The Literature has been reviewed based on above mentioned techniques.

(Shen, Wang and Zhu 2010), proposed a new multi-lead ECG classification technique. This method introduced an improved ICA method at the feature extracting stage. The ECG is divided into three parts (P peak, QRS complex and ST interval) in this method. The feature of single lead is first constructed by these three feature vectors after that to achieve a multi-lead feature vector 12 single lead feature vectors are mixed gradually and then the Support Vector Machine (SVM) is adopted for 2-allocation experiments and multi-allocation. 2500 feasible records

collected from almost 500 people and data from MIT-BIH Arrhythmia Database is used in experiments simultaneously. The experimental data has the overall average accuracy is 98.18% and the average sensitivity is 98.68%.

(Langley, Bowers and Murray 2010) suggested an algorithm based on PCA to evaluate the differences in ECG analysis and then enforced this algorithm to the production of surrogate respiratory signals with the help of single-lead ECGs. This caused variations in ECG features, P and T waves and QRS complexes were expressed by the PCA. For the respiratory signal the ECG features assessment and principal components produced the best alternatives. 20 subjects perform controlled respiratory for 180s at 4, 6, 8, 10, 12 and 14 breaths per minute and regular respiratory ECG and respiratory signals were registered. The breathing process has been carried out from the ECG using 3 methods: the algorithm depended on PCA and 2 settled methods depending on R to R distance and amplitude of QRS complex. Breathing obtained by ECG was correlated to the registered respiratory signal. PCA method enforced to ECG was the top ranking algorithm for both correlation and coherence. In this algorithm Correlation and coherence were significantly larger as compared to the RR algorithm. A new algorithm has been provided by PCA by which both berthing and non breathing beat to beat changes in the ECG signal are analyzed.

(Mishra and Raghav 2010) proposed nearest neighbor classifier based on a local fractal dimension for ECG based arrhythmia classification. At every discrete interval of the ECG signal, Local fractal dimension (LFD) is considered as the feature. To find the ECG beat class in the feature space a nearest neighbor algorithm is used. Depending on the R to R distance information based Euclidean length the nearest neighbor is found in this work. In the current work to estimate the LFD which depends on the two algorithms, two classification algorithms were validated i.e. variance depended fractal dimension evaluation depended nearest neighbor classifier and power spectral density depended fractal dimension evaluation depended nearest neighbor classifier. Depending on the various figures of merit their performances are evaluated. The performance of is 91.07% for arrhythmia and 93.15% for normal beats individually. The proposed method gives

better result than the method which uses straight forward template matching classifier which provided 38.21% general average sensitivity.

(Thanapatay, Suwansaroj, and Thanawattano 2010) presented a method of ECG printout with Support Vector Machines and Principle Components Analysis for ECG beat classification. To find out the abnormalities of heart's behavior ECG developed from the heart of human is used. In this paper ECG beats have been classified in four categories using ECG shapes i.e. normal beat (N), right bundle branch block beat (R), left bundle branch block beat (L) and ventricular premature beat (V). This method used the discrete wavelet transform (DWT) having level 3 of Daubechies 1 afterwards digital filter to extract the shape of ECG. Then PCA and SVM are adopted for creating a classifier model to use along the ECG printout based on paper. The appearance of ECG obtained from ECG printout is then prepared using few techniques of image processing i.e. noise rejection, red grid removing, time-series ECG extraction and image thinning. To find the time-series ECG signal prior to the classification, MIT-BIH arrhythmia records is used for SVM training and calculation and the result obtained from given classifier using this database is 99.6367% with LIBSVM.

(Zellmer, Shang and Zhang 2009) proposed an extremely correct ECG beat classification system. This method designs 3 different feature vectors from every beat by combining the continuous wavelet transformation included with time domain movement investigation then to train three distinct SVM classifiers every feature vectors are used separately. At the time of data classification each beat is being classified these three classifiers independently and the result of classification system based on the multi classifier is determined by polling among these three separate classifiers. Overall accuracy obtained from the multi classifier dependent system is 99.72%. The accuracy obtained from this method is greater as compare to the individual performing SVM classifiers also than the ECG beat classification systems presented previously which shows the effectiveness of this technique.

(Martis, Chakraborty and Ray 2009) presented a method for cardiac abnormality detection based on electrocardiogram (ECG) with Gaussian mixture model (GMM). A combination of 12 features explaining including data variability of 99.7% was achieved using PCA with the help of residual error signals for GMM dependent classification. For validating 40% and to train the

classifier 60% data is used. Overall accuracy obtained from this method was 94.29%. It is also observed that for GMM based classifier Bhattacharya bounds and Chernoff bound lead to minimum error.

(Martis, Chakraborty and Ray 2009) presented a new approach to extract the feature of ECG signal with the help of coefficients of DWT and then PCA. Therefore to represent the given data less number of features will be used. The features were compressed in time domain using PCA in conventional scheme which was out performed by the proposed method. The principal components of the sub bands of DWT signal in the compact supported basis space shows the data better than in the time domain which is confirmed by means of statistical test of significance. For better discrimination the features of wavelet have the more importance than the features in time domain.

(Wai, Ming, and Bin 2008) presented a new method for the detection of the rhythm of heart using assimilation of orthogonal polynomial decomposition (OPD) based on Hermite and classification of support vector machines (SVMs). The QRS interval is now not completely parameterized using fiducially points (spike, offset and onset) using proposed morphological feature characterization, The Hermite characterization gives features more stable and comparatively unresponsive to the morphological variations. All the characteristics and acceptable generalized function of the SVMs classifier were combined and generated the output of beat recognition precisely.

(Guler and Ubeyli 2007) proposed a novel approach for electrocardiogram (ECG) beats classification depending on the multiclass SVM implementation in combination to the fault improving output codes. In these method four types of ECG beats of Physiobank records were analyzed. DWT was used to decompose the ECG signals into time–frequency representations. To represent the signals wavelet coefficients were calculated. The purpose of this study is the classification of ECG signals using the combining wavelet coefficients with multiclass SVM. The purpose of this is to obtain a normalized classification method as well as to interpret the proof about the obtained details.

(Tasoulis et al. 2004) proposed Neural Network Training which is online for the system of Automatic Arrhythmia Episode Detection. Due to shortage of nutrients and oxygen to the contractile cells Myocardial arrhythmia occurs which may cause to myocardial infarction with its severe consequence of arrhythmia and heart failure. The ECG is a part of bioelectric signal, which provides important and relevant information about the heart state. Since it is very easy and non–invasive to record ECG hence it provides reliable arrhythmia detection. The entire depolarization wave shape is frequently affected by Ischemic changes in the ECG signal.

(Shook et al. 1989) estimated the average of the ST deviation (ST segment depression at the point J80, it is a point that lies 80 ms after J), the average of the ST absolute deviation (maximum ST segment depression) and the average of the ST slope (slope between the points J and J80) in every 30s of the ECG signal. To classify the ischemic episodes they used certain rules (0.75mm for the deviation, 1mm for the absolute deviation and zero for the slope). The second set of rules (1mm for the deviation, 1mm for the absolute deviation and zero for the slope) was used in this method for the classification of each ischemic episode as "probable" or "definite" based on the set of rules is triggered. The final output of the system was the margins of the "probable" and "definite" ischemic episodes. Positive predictive accuracy and Sensitivity obtained from this method was 96% and 90%, respectively.

2.1 Gaps in Literature

To accentuate the R peak various signal processing techniques used wavelet filters in preprocessing stage which also suppresses the noises but defeated by the selection problem of mother wavelet. In few of the techniques real-time detection method is proposed but it depends on a suitable choice of the bandwidth for the bandpass filter. Few methods have been discussed in literature on FPGA implementation of QRS detection but these methods used a non pipelined architecture making it unable to run in real time. No method has been developed to predict the types of diseases based on ECG and their implementation on FPGA.

3. DESCRIPTION OF BROAD AREA

Every heart contraction produces an electrical impulse due to which muscle squeezes and pumps blood from the heart. This electrical impulse can be registered fairly simply by placing electrode nodes on human chest and limbs. The heartbeat produces a series of waves with a time-variant morphology called the heart rhythm in terms of bits per minute which may be simply calculated by counting the easily detectable waves, (Pan and Tompkins 1985; Benitez et al. 2001; Debbabi 2010). The electrocardiogram ECG is a part of bioelectric signal, which provides important and relevant information about the heart state. Based on the difference in position, chest configuration, anatomy of the heart, age, size, relatively body weight and various other factors, ECG of every person is different, (Kohler 2002; So and Chan 1997).

Heart's electrical activity is depending on re-polarization and depolarization of myocardial cells. The cardiac cycle originates in the sinoatrial node running from the atriums and goes down throw the ventricles and generating the atrium contraction. Finally depolarization then propagates to the ventricles and approaches to the Purkinje fibers and then re-polarization of the heart tissue takes place.

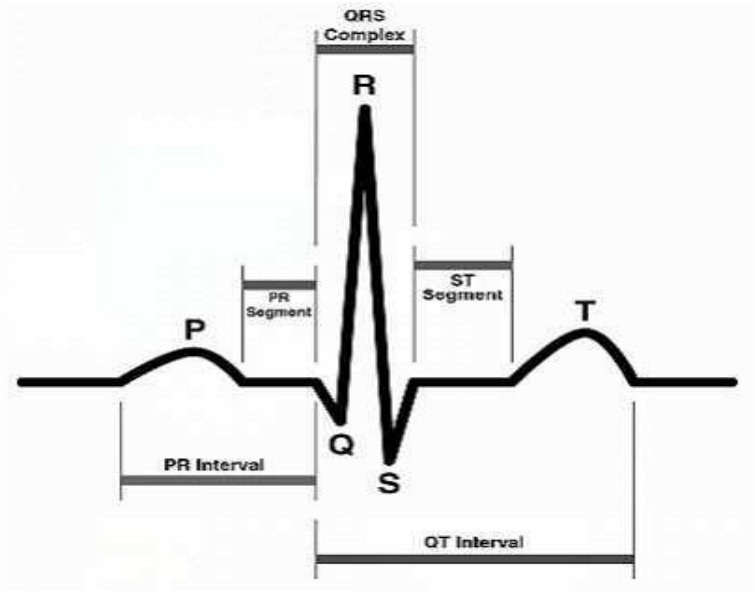

Figure 1: A normal ECG signal

ECG waveform

Each beat is consists of three different waves, P wave, QRS and finally T wave (ventricular repolarization). In the ECG signal, these three waves are continuously repeated, representing heartbeats and clinical status of the activity of heart over the time, (Manikandan and Soman 2012; Hamilton and Tompkins 1986). The ECG voltage level fall in the range 0.05 to 5mV and the frequency components of the ECG signals lies in the band 0.05 to 100Hz for a normal subject, (Skordalakis 1986; Andreao, Dorizzi and Boudy 2006).

Amplitude

P-wave: represents the contraction of the atria — 0.25 mV

R-wave — 1.60 mV

Q-wave — 25% R wave

T-wave — is the relaxation of ventricles 0.1 to 0.5 mV

QRS complex: the current generated when the ventricles depolarize that results in contraction of the right and left ventricles.

Table1: Amplitude and time intervals between different segments of ECG

Sl. no.	Parameter Points	Amplitude (mV)	Time duration(msec)
1	P wave	0.1-0.2	60-80
2	PR-segment	-	50-120
3	P-R	-	120-200
4	QRS	-	80-120
5	ST-segment	-	100-120
6	T –wave	0.1-0.3	120-160
7	S-T	-	320
8	R-R	-	400-1200

ECG signal can be used to detect Cardiac arrhythmias. The normal heart rate is about 70 beats /min. Any change in the heart rate is called Arrhythmia, which can be broadly classified in two categories based on R-R interval i.e. Bradycardia and Tachycardia (Yeh, Wang and Chiou 2009; Anigraphy, Rakshit and Sahu 2016). If heart rate is slow or below 60 beats /min and the distance RR> 1.2s during activity then Bradycardia occurs and if the heart rate is high or above 100 beats

/min and the distance RR <0.6s, this indicates a disorder called Tachycardia (Prasad and Varadarajan 2013).

Once the features present in an ECG signal get determined then various arrhythmias can be detected like Bradycardia, Tachycardia, Supraventricular Tachycardia, Ventricular Tachycardia, Bundle Branch Block and Incomplete Bundle Branch Block.

A. Signal processing

ECG signal will be used for arrhythmia classification. Signals that are produced by body organs are mixed with each other or by noise. Separating the desired signal from mixed signal and extract the useful signal is kind of Signal processing (Chaitanva et al. 2011).

The main parts of the algorithm are:

• To obtain maximum value of signal to noise ratio, recording should be near to the signal source.

• Detection method based on the least amount of false positives (FP) and the minimum value of false negative (FN) be used.

• Noise removing with using filters.

The band of ECG signal frequency is between 15 to 150 Hz, muscle activity. Noise Frequency is above 150 Hz; baseline oscillation frequency is lower than 1 Hz (Baseline noise through electrode get in touch impedance and body changes).

B. A standard MIT/ BIH database for calculation of ECG

The algorithm to obtain and classify the ECG for the detection of cardiac arrhythmias is split in many stages. In the initial stage, for noise elimination from the recorded ECG signals, the filter techniques are adopted. After that the QRS peak finding techniques try to obtain the origin and closing points of the QRS complex. The required information is extracted from this QRS complex obtained from ECG signal of MIT/BIH Arrhythmia Database.

4. OBJECTIVES

4.1 Problem Formulation

The existing techniques for R peak detection are not accurate and take longer time to detect QRS complex. There is no such system in the existing state of art which uses ECG with other body parameters for efficient diagnosis of heart disease for recorded and real time data. And no method has been developed to implement FPGA to detect various arrhythmias

4.2 Objectives

The objective of this work is to design, develop and implement a robust system that will detect arrhythmias like Bradycardia, Tachycardia, Supraventricular Tachycardia, Ventricular Tachycardia, Bundle Branch Block and Incomplete Bundle Branch Block based on the features obtained from QRS complex and few other body parameters like Blood Pressure and Sugar etc.. This system can be used for tele-monitoring of patient or to keep 24x7 watch on the patient.

- To detect the QRS complex using Shannon energy envelope estimator accurately and with minimum computation time and then extract normalized features.
- To classify the arrhythmia efficiently based on ECG signals.
- To precisely determine the disease with the help of arrhythmia class, BP, Sugar and other body parameters using MATLAB.
- To develop and implement above mentioned algorithm using HDL (Verilog), on FPGA.
- To implement this system for Real Time application.

5. METHODOLOGY

The heart disease diagnosis scheme is composed of data acquisition, feature extraction and normalization, feature reduction, classification, additional feature extraction, and fusion algorithm. The flow chart of the proposed scheme is shown in figure 2. ECG signals have been used for feature extraction. Once the features present in an ECG signal get determined then further additional parameter like BP, sugar level etc. will be taken in consideration for final

disease identification. Various arrhythmias can be detected like Bradycardia, Tachycardia, Supraventricular Tachycardia, Ventricular Tachycardia, Bundle Branch Block and Incomplete Bundle Branch Block.

1. **Preprocessing** To calculate the function of the proposed method, ECG records of MIT-BIH arrhythmia database shall be used. The signal is decomposed using wavelet filters and undesired part will be eliminated by applying thresholding on wavelet coefficients.

2. **QRS complex detection** Shannon energy envelop of the signal shall be calculated, as peaks of the signal coincide with peak of the envelop. Hence by locating peak of envelop R-peak location shall be evaluated and so shall be QRS complex obtained.

3. **Feature extraction** Signal shall be decomposed using discrete wavelet transform (DWT) and only frequency sub-band containing QRS complex shall be used for further processing. The FFT and statistical parameters of selected sub-band shall be used as feature.

4. **Disease diagnosis** The output of the classifier with measurement of BP and Sugar levels shall used to decide the existence of disease.

5. **FPGA Implementation** This system shall then implemented on FPGA for hardware implementation using Hardware Description Language (HDL) coding that will be written in Verilog language.

6. **Real Time Application** This system shall then designed to work on real data (i.e. ECG, BP, Sugar etc. of same person) taken from hospital or from a person directly.

Flow Chart for the proposed system is given in Figure 2:

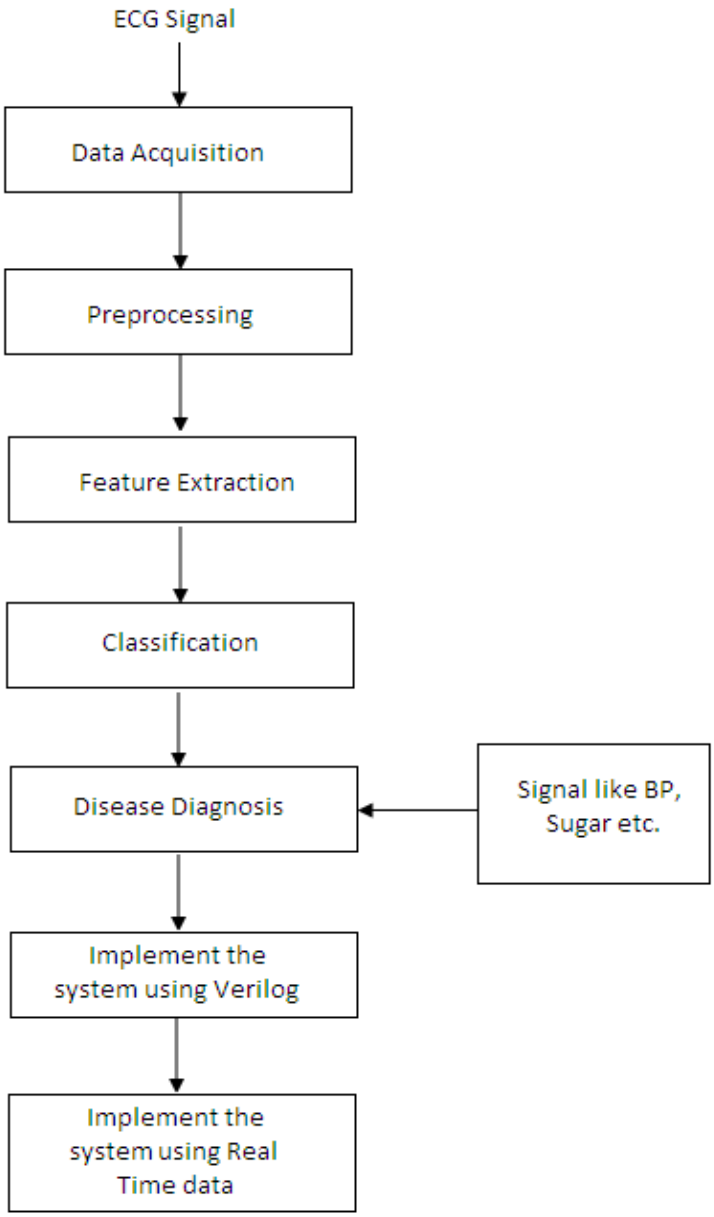

Figure 2: Flow Chart for implementation of disease detecting system on FPGA

The Block diagram used in the system is described in Figure 3 in detail.

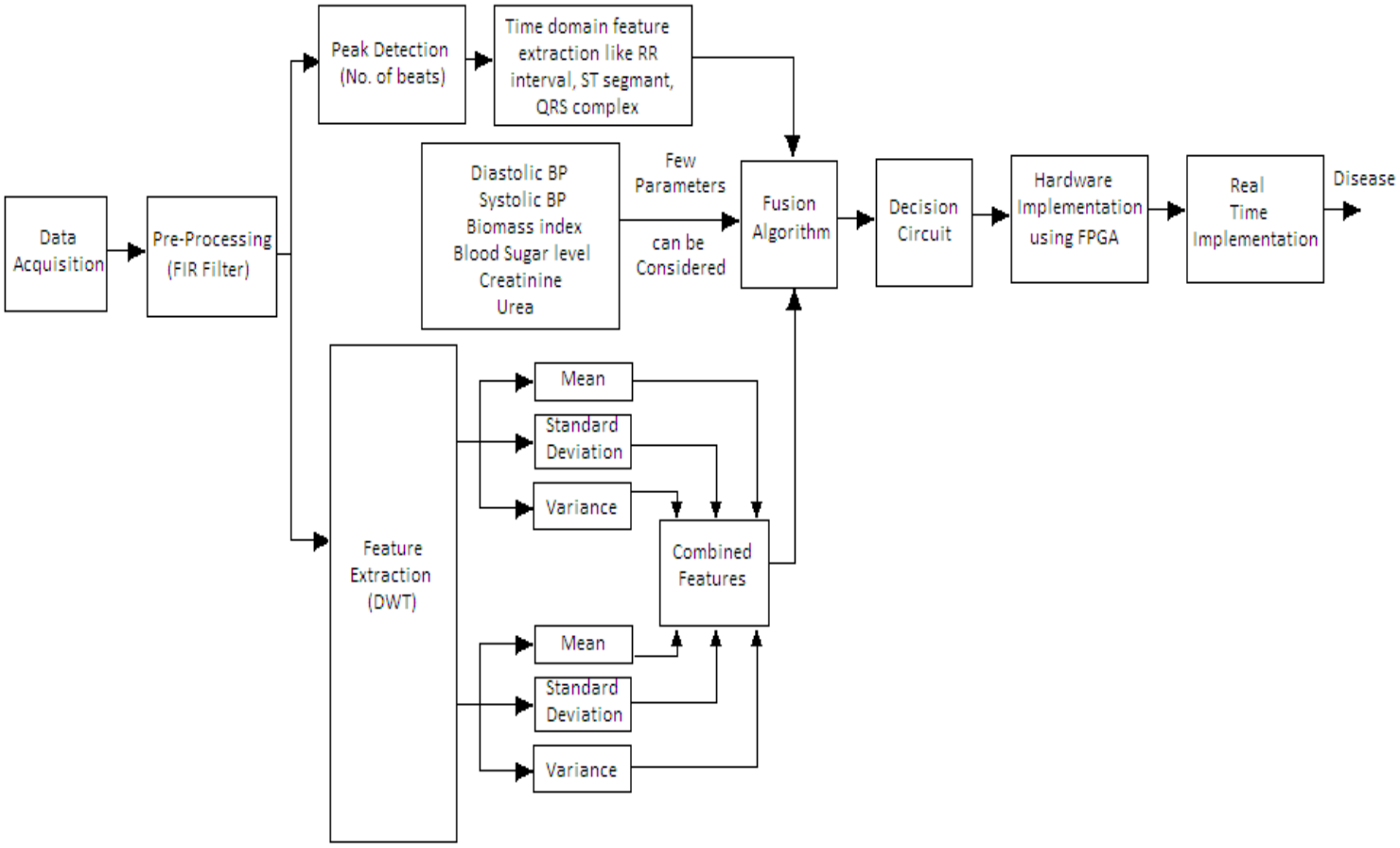

Figure 3: The block diagram for implementation of disease detecting system on FPGA

1. **Denoising**

   Several noises or undesired interferences mixed with the ECG signals and corrupt it such as influence of the muscle noise, the baseline wander, the power line interference, frequency noise impacts and electro mayogram (EMG), (Suárez et al. 2007; Pahlm and Sörnmo 1984). So before applying any algorithm for detection, the preprocessing of the signal should be done, FIR Filter followed by Wavelet technique is used for removal of baseline wander and high frequency noise to smoothen unfiltered data which is passed through baseline wandering removal function (Das and Chakraborty 2012).

2. **Feature extraction and Normalization**

In the feature extraction procedure, features of ECG signal like R-R interval, P wave, QRS interval, ST segment, wavelet features, statistical features and FFT etc. are extracted, which are further used in the classification of the signal. Fraction of signal around the R peak will be extracted as the time-domain features, since the R peak of ECG signals is an important index for cardiac diseases and has highest amplitude in ECG signal (Arzeno, Deng and Poon 2008; Hongyan and Minsong 2008). However, the signal amplitude biases of the waveforms of the ECG beat samples are inconsistent due to instrumental and human differences. Hence, we will utilize the Z-score method to normalize the features. Through the Z-score method, the mean value of each ECG sample is firstly subtracted from each ECG sample to eliminate the offset effect, and then divided by its standard deviation. This procedure results in a normalized ECG beat sample with zero mean and unity standard deviation.

3. **DWT**

   After preprocessing, heart beat is estimated and given to the decision circuit. To extract features of the preprocessed ECG signal is applied to the discrete wavelet transform (DWT). The DWT will split the data into low pass signal and high pass signal and obtaining the three kinds of features such as mean, standard deviation and variance of the ECG signal.

4. **Additional parameter**

   Once type of arrhythmia is known, we need additional parameters to identify the disease. This happens because one kind of arrhythmia can lead to several diseases. The additional parameters can be blood pressure, sugar level etc. Along with the ECG signal analysis, we have measuring the Heart Disease, RBBB, LBBB etc.

5. **Fusion algorithm**

   An algorithm will be developed which can take decision about the disease detection based on arrhythmia information and additional parameter information.

Hardware implementation

Algorithms are supposed to be main idea of any system but without hardware implementation, it is just an idea. So, we need hardware realization that considered being complete system. But it should be optimized otherwise it can’t be considered as best. This developed system will be

implemented using Hardware Description Language (HDL) coding that will be written in Verilog language. From this HDL hardware, we can check power analysis, timing analysis (delay between input and output of system), and how much hardware it contain to simulate proposed algorithm.

Real Time Implementation Once this system has been designed is now implement to work on real data (i.e. ECG, BP, Sugar etc. of same person) taken from hospital or from a person directly.

6. EXPECTED OUTCOME OF THE RESULT

The proposed system will precisely detect the cardiovascular disease commonly found in humans. This system can be used for tele-monitoring of patient or to keep 24x7 watch on the patient. Various arrhythmias can be detected like Bradycardia, Tachycardia, Supraventricular Tachycardia, Ventricular Tachycardia, Bundle Branch Block and Incomplete Bundle Branch Block. This algorithm can also be used in various applications for biomedical signal analysis such as in implantable and wearable systems.

7. PROPOSED TIME FRAME (GANTT CHART)

Research Plan													
	Sem1 (June' 13)	Sem 2 (Dec' 13)	Sem3 (June' 14)	Sem 4 (Dec' 14)	Sem 5 (June' 15)	Sem 6 (Dec' 15)	Sem 7 (June' 16)	Sem 8 (Dec' 16)	Sem 9 (June' 17)	Sem10 (Dec' 17)	Sem11 (June' 18)	Sem12 (Dec' 18)	Sem13 (June' 19)
Course Work													
Literature Review													
International Paper Presentation and Publication													
Data Collection													
Data Study													
Interpretation of Data													
Thesis Submission													

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